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SN Galani
Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat, India

RB Madariya
Main oilseeds Research Station, Junagadh Agricultural University, Junagadh, Gujarat, India

SK Parmar
Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat, India

JS Sorathiya
Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat, India

Corresponding Author:
SN Galani
Millet Research Station, Junagadh Agricultural University, Jamnagar, Gujarat, India

Study of heterosis in F_1 and F_2 generations of pearl millet [*Pennisetum glaucum* (L.) R. Br.]

SN Galani, RB Madariya, SK Parmar and JS Sorathiya

Abstract
The experimental material, consisting of 101 entries including 10 parents, 45 crosses, 45 F_2s and one check hybrid (GHB 732) was raised in a Randomized Block Design with three replications at the Pearl millet Research Station, JAU, Jamnagar during *Summer* 2020. The results revealed that the best three hybrids identified on the basis of *per se* performance and standard heterosis for grain yield per plant *viz*., J 2601 x J 2340, J 2597 x J 2340 and J 2517 x J 2479 also depicted significant positive standard heterosis over GHB 732 for important yield contributing traits.

Keywords: Heterosis, heterobeltiosis, pearl millet, hybrid

1. Introduction
Pearl millet is world's sixth important cereal crop after rice, wheat, maize, barley and sorghum. In India, it is fourth most important food grain crop after rice, wheat and sorghum. Pearl millet is diploid (2n=14) in nature known as bajra, cattail millet and bulrush millet in different parts of the world. As an arid and semi-arid crop, it is the component of dry land system and usually grown on the soil with depleted fertility, which receives rainfall of 150 to 750 mm per annum. It occupies an area of 7.41 million ha with an average production of 10.30 million tones and productivity of 1391 kg/ha (Anon., 2021) [1]. Exploitation of hybrid vigour is considered to be one of the outstanding achievements of plant breeding in pearl millet. In heterosis breeding program, it is of paramount importance to evaluate available, useful and promising diverse parental lines and their cross combinations for grain yield and different characters.
The improvement in grain yield, which is considered as a final product in almost all the crop plants, is usually obtained by screening, evaluating and selecting the suitable genotype from a huge collection of germplasm and accumulating desirable genes in a productive genotype for commercial cultivation. The phenomenon of heterosis has attracted the attention of plant breeders due to its conspicuous effect on economic characters (Shull, 1908). Heterosis has been successfully exploited in many cross pollinated crops like maize, pearl millet, sorghum and many others. Commercial exploitation of heterosis is easier in the above mentioned cross pollinated crop species because of the ease in producing hybrid seeds and availability of male sterility systems.

2. Materials and Methods
The experimental materials comprised of ten promising genotypes of pearl millet used in half diallel crossing programme *viz*., J 2597, J 2517, J 2601, J 2602, J 2479, J 2569, J 2340, J 2591, J 2454, J 2372 and their 45 crosses and one standard check GHB 732. The experiment consisting of 10 parents and their 45 hybrids (F_1) and 45 F_2 was laid out in randomized block design with three replications at the Pearl Millet Research Station, Junagadh Agricultural University, Jamnagar during *Summer*-2020. The analysis of variance was performed to test the significance of differences among the genotypes for all the characters following fixed effect model as suggested by Panse and Sukhatme (1995) [7]. Theoretically heterosis is the deviation of F_1 from the mid parental value. But, an increase in F_1 over poor parents may not be of practical importance. Therefore, in the present investigation, heterosis was estimated over better parent (BP), which is referred to as heterobeltiosis as per Fonseca and Patterson (1968) [4]. In addition, an increase in F_1 over the standard check hybrid (standard heterosis) is of commercial importance.

3. Result and Discussion
In the present study, considerable high heterosis in certain crosses and low in other revealed that the nature of gene action varied according to the genetic makeup of the parents. Several crosses exhibited conspicuous level of heterobeltiosis and standard heterosis for different characters. Range of heterosis as well as number of crosses exhibiting significant positive as well as negative heterobeltiosis and standard heterosis are presented in Table 1.
With respect to the performance of hybrids for grain yield per plant, it was observed that 27 hybrids over better parent and 14 hybrids over standard check (GHB 732) exhibited significant and positive heterosis (Table. 1). The range of heterosis over better parent was from -11.59 to 64.73%, while over standard check, it ranged from -21.13 to 38.59%. The cross J 2591 x J 2372 depicted significantly the highest and positive heterobeltiosis (64.73%), standard heterosis (27.61%) as well as the highest grain yield per plant (33.0 g). High heterosis for grain yield in pearl millet has also been reported by Govindraj *et al.* (2011) [5],

Bhadaliya *et al.* (2013) [3], Singh *et al.* (2015) [8], Nandaniya *et al.* (2016) [6] and Bhaskar *et al.* (2017) [2]. With regard to days to 50% flowering (Table 1), nine crosses exhibited heterobeltiosis in desired (negative) direction and 36 crosses were found significantly earlier over standard check. The cross J 2479 x J 2372 was found earliest among the crosses over standard check followed by J 2597 x J 2601, J 2602 x J 2479 and J 2517 x J 2372. For days to maturity, out of 45 hybrids, seven and 28 hybrids showed significant and negative heterosis over better parent and standard check, respectively. The cross combination J 2479 x J 2372 recorded the highest desirable heterosis over standard check followed by J 2597 x J 2601, J 2602 x J 2479 and J 2517 x J 2372. None of the crosses showed significant and desirable (positive) heterobeltiosis and standard heterosis for number of effective tillers per plant (Table 1). Two cross combinations exceeded heterosis over better parent for earhead length (Table 1), while 27 cross combinations showed significant positive standard heterosis for this trait. For dry fodder yield per plant, out of 45 crosses, 22 and 10 crosses manifested significant and desirable (positive) heterosis over better parent and standard check, respectively. The crosses J 2601 x J 2340, J 2517 x J 2601, J 2597 x J 2340 and J 2597 x J 2591 recorded positive standard heterosis for dry fodder yield per plant. Ten most significant heterotic cross combinations for grain yield per plant were J 2601 x J 2340, J 2597 x J 2340, J 2517 x J 2479, J 2591 x J 2372, J 2597 x J 2591, J 2517 x J 2601, J 2597 x J 2454, J 2602 x J 2340, J 2597 x J 2517 and J 2517 x J 2340. (Table 2)

Table 1: Range of heterobeltiosis (H_1) and standard heterosis (H_2) along with number of crosses showing significant estimates for various characters in pearl millet

Sr. No.	Characters	Range		Number of crosses showing significant estimates			
		H_1 (%)	H_2 (%)	H_1 (%)		H_2 (%)	
				+Ve	-Ve	+Ve	-Ve
1	Days to 50 % flowering	-11.27 to 15.67	-14.29 to 5.44	18	9	2	36
2	Days to maturity	-8.62 to 11.82	-10.92 to 3.36	21	7	2	28
3	Plant height (cm)	-22.28 to 9.41	-5.71 to 33.93	2	41	34	1
4	Number of effective tillers per plant	-25.00 to 20.00	-33.33 to 3.70	0	5	0	12
5	Earhead length (cm)	-36.46 to 20.29	-11.43 to 37.78	2	35	27	1
6	Earhead girth (cm)	-22.57 to 18.99	-12.13 to 32.36	14	20	32	2
7	Weight of dry earhead (g)	-13.87 to 49.26	-15.51 to 37.81	23	0	19	0
8	Grain yield per plant (g)	-11.59 to 64.73	-21.13 to 38.59	27	0	14	1
9	Dry fodder yield per plant (g)	-22.31 to 47.35	-22.81 to 34.68	22	2	10	2
10	1000-grain weight (g)	-28.52 to 23.51	-15.23 to 26.17	9	24	22	9
11	Harvest index (%)	-18.38 to 39.21	-13.95 to 17.14	7	1	3	1

Table 2: Ten best performing hybrids for grain yield per plant on the basis of *per se* performance along with heterobeltiosis (H_1) and standard heterosis (H_2) for component characters in pearl millet

Sr. No.	Hybrids	Grain yield per plant (g)	Heterosis (%)				Significant desirable standard heterosis for component traits
			H_1		H_2		
1	J 2601 x J 2340	32.80	49.09	**	38.59	**	DF, WD, FY
2	J 2597 x J 2340	32.00	45.45	**	35.21	**	DF, DM, PH, EL, WD, FY, HI
3	J 2517 x J 2479	30.80	54.00	**	30.14	**	DF, DM, PH, EL, EG, WD, FY, HI
4	J 2591 x J 2372	30.20	64.73	**	27.61	**	DF, DM, PH, WD, FY, TW
5	J 2597 x J 2591	30.00	52.54	**	26.76	**	DM, PH, EL, WD, FY
6	J 2517 x J 2601	29.47	49.83	**	24.51	**	DM, PH, WD, FY
7	J 2597 x J 2454	29.33	44.26	**	23.94	**	PH, EL, WD, FY, TW, HI
8	J 2602 x J 2340	29.33	33.33	**	23.94	**	DF, DM, PH, EL, EG, WD, FY,TW, HI
9	J 2597 x J 2517	28.80	46.44	**	21.69	**	WD, FY, EG, TW, HI
10	J 2517 x J 2340	28.07	27.58	**	18.59	**	DF, DM, PH, EL, WD, FY, TW

** Significant at 1 % level of significance

DF= Days to 50% flowering, DM= Days to maturity, PH= Plant height, NE= Number of effective tillers per plant, EL= Earhead length, EG= Earhead girth, WD= Weight of dry earhead, FY= Dry fodder yield per plant, TW= 1000-grain weight, GY=Grain yield per plant and HI= Harvest index

4. Conclusions

In the present study, considerable high heterosis in certain crosses and low in other revealed that the nature of gene action varied according to the genetic makeup of the parents. Significant level of positive and negative heterobeltiosis and standard heterosis in several crosses for almost all the traits also indicated genetic diversity of parents used in present investigation. The extent and magnitude of heterotic effects varied form cross to cross and character to character. The magnitude of standard heterosis in the positive direction was high for weight of dry earhead, grain yield per plant, dry fodder yield per plant; medium for harvest index and earhead girth. Similarly, the magnitude of standard heterosis in the negative direction was high for days to 50% flowering, plant height, earhead length and 1000-grain weight.

The hybrids which registered higher values of heterotic effect for grain yield per plant also exerted higher amount of heterosis for at least three or more yield contributing component characters, which support the combinational heterosis theory for grain yield per plant in pearl millet.

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